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Status Report

NsG-455

This status report covers the period of June 1, 1963 through November 30, 1963. Since the grant was not accepted before September 11, 1963, and University regulations allowed no expenditures before this date, no actual experimental work other than testing of equipment could be undertaken during the report period. Within a few weeks from the acceptance major equipment items such as a multichannel analyzer, a wide band scope and counting apparatus and supplies were ordered but were mostly not delivered during the report period.

Theoretical Work:

Lithium-drifted germanium semiconductor detectors have shown promise of revolutionizing γ-ray spectroscopy[1,2]. In this program we have started an investigation of a method for increasing the active volume of semiconductor detectors of this and other types. The small useful volume of present detectors of this type is the major limitation on their use. Either the efficiency is very small, as for γ rays, or the useful particle energy is limited, as for charged particles.

The method to be used to increase the active volume involves a combination of lithium-drifting and special geometrical configurations. Lithium-drifting is now a standard technique, but the usual planar configuration limits the depth due to internal thermal runaway during drifting. Also, in use the electric field at the rear of the depletion depth is zero, and this value is approached quadratically, so that collection problems accrue in that region.

Cylindrical geometry is one way to reduce both of these problems. A solution to Poisson's equation in cylindrical geometry for a constant charge depletion density (a first approximation):

$$\nabla^2 \phi = \frac{1}{r}\frac{\partial}{\partial r}\left(r \frac{\partial \phi}{\partial r}\right) = -4\pi\rho \, , \tag{1}$$

is the following:

$$\phi = \pi\rho \left(r_2^2 - r^2\right) + \left[V_o - \pi \frac{\left(r_2^2 - r_1^2\right)}{\ln \frac{r_2}{r_1}}\right] \ln \frac{r_2}{r} \, , \tag{2}$$

where ρ is the depletion density
r_2 is the outer radius
r_1 is the inner radius
V_o is the applied bias voltage

The radial component of field is, in this case:

$$E_r = -\nabla\phi = 2\pi\rho r - \frac{1}{r}\left[\frac{V_o - \pi\rho\left(r_2^2 - r_1^2\right)}{\ln \frac{r_2}{r_1}}\right] \tag{3}$$

With the appropriate choice of sign for V_o, the second term is always additive to the first, and the electric field increases toward the "rear" (inside) of the depletion region. This permits a reduction in ohmic heating during the drifting process and increases collection efficiency in that region during operation. A similar improvement of the depletion density occurs even when other assumptions are made about the spatial dependence of the depletion density.

Conventional silicon surface barrier and diffused junction detectors have been fabricated for several years in our laboratory. In conjunction with development of the lithium drifted detectors, we plan to study defects in these conventional detectors. Enigmas of surface conditions still prevent a clear decision as to whether encapsulated or "open" type detectors are more reliable and give a higher yield. The effect of different atmospheres and pressure variation has had only slight study.

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1. G. T. Ewan, preprint.
2. A. J. Tavendale, preprint.